CLAIMS

1. An electron-emitting device comprising:

a cathode electrode;

a layer electrically connected to the cathode electrode; and

a plurality of particles, each comprising as a main component a material which has resistivity lower than resistivity of a material of the layer, wherein

the plurality of particles are arranged in the layer; and

a density of the particles in the layer is $1 \times 10^{14}/cm^3$ or more and $5 \times 10^{18}/cm^3$ or less.

2. An electron-emitting device comprising:

a cathode electrode;

a layer electrically connected to the cathode electrode; and

a plurality of particles, each comprising as a main component a material, which has resistivity lower than resistivity of a material of the layer, wherein,

the plurality of particles are arranged in the layer; and

a concentration of a main element of the particles with respect to a main element of the layer is 0.001 atm% or more and 1.5 atm% or less.

3. An electron-emitting device comprising:

a cathode electrode;

a layer electrically connected to the cathode electrode; and

a plurality of particles, each comprising as a main component a material which has resistivity lower than resistivity of a material of the layer, wherein

the plurality of particles are arranged in the layer;

a density of the particles in the layer is $1 \times 10^{14}/cm^3$ or more and $5 \times 10^{18}/cm^3$ or less; and

a concentration of a main element of the particles with respect to a main element of the layer is 0.001 atm% or more and 1.5 atm% or less.

4. An electron-emitting device comprising:

a cathode electrode;

a layer which is arranged on the cathode layer and contains carbon as a main component; and

at least two particles which are arranged so as to be adjacent to each other in the layer and comprises metal as a main component, wherein

one of the adjacent two particles is arranged to be nearer to the cathode electrode than the other particle; and

the metal is metal selected from Co, Ni, and Fe.

5. An electron-emitting device comprising:

a cathode electrode; and

a layer connected to the cathode electrode,

wherein

a plurality of groups of particles, each group being constituted by at least two particles adjacent to each other, are arranged in the layer;

each of the particles comprises as a main component a material which has resistivity lower than resistivity of a material of the layer,

the adjacent two particles are arranged in a range of 5 nm or less;

one of the adjacent two particles is arranged to be nearer to the cathode electrode than the other particle; and

the plurality of groups of particles are arranged apart from each other by an average film thickness of the layer or more.

6. An electron-emitting device comprising:

a cathode electrode; and

a layer connected to the cathode electrode, wherein

a plurality of groups of particles, each group being constituted by at least two particles which comprise metal as a main component and are adjacent to each other, are arranged in the layer;

the layer comprises as a main component a material which has resistivity higher than resistivity of the particles;

the adjacent two particles are arranged in a

range of 5 nm or less; and

one of the adjacent two particles is arranged to be nearer to the cathode electrode than the other particle.

7. An electron-emitting device comprising:

a cathode electrode; and

a layer which is connected to the cathode electrode and comprises carbon as a main component, wherein

a plurality of groups of particles, each group being constituted by at least two particles which comprise metal as a main component and are adjacent to each other, are arranged in the layer;

the plurality of groups of particles are arranged apart from each other by an average film thickness of the layer or more; and

a concentration of the metal in the layer is lower on a surface side of the layer than on the cathode electrode side.

8. An electron-emitting device comprising:

a cathode electrode; and

a layer which is connected to the cathode electrode and comprises carbon as a main component, wherein

a plurality of groups of particles constituted by at least two particles, which comprise metal as a main component, being adjacent to each other are

arranged in the layer,

one of the adjacent two particles is arranged on the cathode electrode than the other particle; and

graphen is included between adjacent particles among at least part of the plurality of particles.

9. An electron-emitting device comprising:

a cathode electrode;

a layer which is electrically connected to the cathode electrode and comprises carbon as a main component; and

a plurality of conductive particles arranged in the layer, each particle comprising carbon as a main component, wherein

the layer contains a hydrogen element of 0.1 atm% or more with respect to a carbon element.

10. An electron-emitting device according to claim 9, wherein the layer contains a hydrogen element of 1 atm% or more with respect to the carbon element.

11. An electron-emitting device according to claim 10, wherein the layer contains a hydrogen element of 20 atm% or less with respect to the carbon element.

12. An electron-emitting device according to any one of claims 1 to 11, wherein surface unevenness of the layer is smaller than 1/10 of its film thickness in rms.

13. An electron-emitting device according to any one of claims 1 to 3, 5, and 6, wherein the layer comprises carbon as a main component.

14. An electron-emitting device according to any one of claims 4, 7, 8, and 13, wherein an average concentration of hydrogen with respect to carbon in the layer is 0.1 atm% or more.

15. An electron-emitting device according to any one of claims 4, 7, 8, 9, and 13, wherein the layer comprising carbon as a main component has an sp^3 bonding.

16. An electron-emitting device according to any one of claims 1 to 3, 5, and 9, wherein the particles comprise metal as a main component.

17. An electron-emitting device according to any one of claims 6 to 8 and 16, wherein the metal is metal selected from Co, Ni, and Fe.

18. An electron-emitting device according to any one of claims 1 to 3, 5, and 9, wherein the particles comprise monocrystal metal as a main component.

19. An electron-emitting device according to any one of claims 1 to 9, wherein the particles have an average particle diameter of 1 nm or more to 10 nm or less.

20. An electron-emitting device according to any one of claims 1 to 9, wherein the layer has a

thickness of 100 nm or less.

21. An electron-emitting device according to any one of claims 1 to 4 and 7 to 9, wherein at least two adjacent particles among the plurality of particles are arranged 5 nm or less apart from each other.

22. An electron-emitting device according to any one of claims 4 to 9, wherein a density of the particles in the layer is $1 \times 10^{14}/cm^3$ or more and $5 \times 10^{18}/cm^3$ or less.

23. An electron-emitting device according to any one of claims 1 to 9, wherein a density of the particles in the layer is $1 \times 10^{15}/cm^3$ or more and $5 \times 10^{17}/cm^3$ or less.

24. An electron-emitting device according to any one of claims 4 to 9, wherein a concentration of a main element of the particles with respect to a main element of the layer is 0.001 atm% or more and 1.5 atm% or less.

25. An electron-emitting device according to any one of claims 1 to 9, wherein a concentration of a main element of the particles with respect to a main element of the layer is 0.05 atm% or more and 1 atm% or less.

26. An electron-emitting device according to any one of claims 1 to 3 and 9, wherein:

the plurality of particles are arranged

dispersedly in the layer as a plurality of groups of particles, each group being constituted by at least two adjacent particles;

one of the two adjacent particles are placed to be nearer to the cathode electrode than the other particle; and

the plurality of groups of particles are arranged apart from each other by an average film thickness of the layer or more.

27. An electron-emitting device according to any one of claims 1 to 26, wherein the surface of the layer is terminated with hydrogen.

28. An electron-emitting device according to any one of claims 1 to 27, further comprising:

an insulating film which is arranged on the cathode electrode and has a first opening; and

a gate electrode which is arranged on the insulting film and has a second opening,

wherein:

the first opening and the second opening communicate with each other; and

the layer is exposed in the first opening.

29. An electron source, wherein a plurality of the electron-emitting devices according to any one of claims 1 to 28 are arranged.

30. An image display apparatus, characterized by comprising the electron source according to claim

29 and a light-emitting member which emits light by being irradiated with electrons.

31. A manufacturing method for an electron-emitting device comprising:

forming a layer which contains metal and comprises a material as a main component, the material having resistivity higher than that of the metal, and

heating the layer in an atmosphere containing hydrogen.

32. A manufacturing method for an electron-emitting device according to claim 31, wherein the atmosphere containing hydrogen further contains hydrocarbon.

33. A manufacturing method for an electron-emitting device according to claim 32, wherein the hydrocarbon is acetylene.

34. A manufacturing method for an electron-emitting device according to any one of claims 31 to 33, wherein the metal is a VIII group element.

35. A manufacturing method for an electron-emitting device according to any one of claims 31 to 33, wherein the metal is metal selected from Co, Ni, and Fe.

36. A manufacturing method for an electron-emitting device according to any one of claims 31 to 35, wherein a heat treatment temperature in the

heating is 450°C or more.

37. A manufacturing method for an electron-emitting device according to any one of claims 31 to 36, wherein the layer comprising a material having resistivity higher than that of the metal as a main component is a layer comprising carbon as a main component.

38. A manufacturing method for an electron-emitting device according to claim 37, wherein the metal is contained in the layer comprising carbon as a main component before the heating at a ratio of 0.001 atm% or more and 5 atm% or less with respect to the carbon element.

39. A manufacturing method for an electron-emitting device according to claim 37, wherein the metal is contained in the layer comprising carbon as a main component before the heating at a ratio of 0.001 atm% or more and 1.5 atm% or less with respect to the carbon element.

40. A manufacturing method for an electron-emitting device according to any one of claims 37 to 39, wherein the film comprising carbon as a main component before the heating has an sp^3 bonding.